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OPERATIONAL USE OF A BIOLOGICAL INSECTICIDE: BACILLUS THURINGIENSIS FOR CONTROL OF THE WESTERN SPRUCE BUDWORM IN NORTHERN NEW MEXICO

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FINAL REPORT
OF THE
1981 PILOT PROJECT

OPERATIONAL USE OF A BIOLOGICAL INSECTICIDE: *BACILLUS THURINGIENSIS* FOR CONTROL OF THE WESTERN SPRUCE BUDWORM IN NORTHERN NEW MEXICO

JUNE 1987

By

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ABSTRACT

In 1981 an aerial application project was conducted in Northern New Mexico to evaluate the operational use of Bacillus thuringiensis (B.t.) against the western spruce budworm. Two formulations of this biological insecticide, Thuricide 16B and Dipel 4L, were applied by fixed-wing aircraft at a rate of one gallon per acre with 8 BIU's per gallon. To determine insecticide efficacy, pest population and host tree damage data was collected for 3 years after treatment, 1981-1983.

Both B.t. formulations tested lowered larval populations to the effective control threshold (5 larvae per 100 buds) during the year of treatment. However, adjusted larval mortality was not as high as expected. Differences in larval densities were found in samples taken at different time intervals after treatment indicating that the effect of Thuricide 16B on larval populations occurs about 7 days earlier than the effect of Dipel 4L. Egg mass densities were highly variable each year collected with no statistical difference found between treated and check blocks for two of three years. During the third year, differences were found between the Dipel 4L and Thuricide 16B; and between the Thuricide 16B and the Check areas. When host damage (percent defoliation) was analyzed, neither formulation provided foliage protection during the year of application. Host damage did decrease the second and third year after application.

INTRODUCTION

In 1981 the U.S. Forest Service conducted a pilot project in the Southwestern Region to determine the value of using Bacillus thuringiensis Berliner (B.t.) for control of the western spruce budworm, Choristoneura occidentalis Freeman. Although two products were registered for control of this pest at the time, neither product had been used on an operational basis in the West[1].

The pilot project was conducted in northern New Mexico in cooperation with the Carson National Forest; the New Mexico Department of Natural Resources, Division of Forestry; and the New Mexico Department of Agriculture, Division of Agricultural and Environmental Services.

The objectives of the pilot project were the following:

1. To evaluate the efficacy of Thuricide 16B and Dipel 4L in controlling western spruce budworm populations under operational conditions. Treatment efficacy was to be indicated by a reduction in larval populations during the year of application.

2. To determine the amount of foliage protection achieved by a single treatment of B.t.

3. To compare the relative effectiveness of the two B.t. products (Thuricide 16B and Dipel 4L) in controlling the western spruce budworm.

4. To identify any formulation, mixing, or application problems associated with B.t. when used on an operational basis.

5. To determine the effect of B.t. applications on budworm populations 2 years following treatment.

Results of the 1981 and 1982 field data were discussed in a progress report of the pilot project (Ragenovich 1983). In this report, results of data collected two years after treatment (1983) are presented. In addition, the results of statistical analysis of budworm population and damage data for all three years of the project are discussed. Based on these findings, final project conclusions are made.

MATERIALS AND METHODS

Project Design

The western spruce budworm pilot control project was conducted in northern New Mexico. The treatment areas were located on private land in the Moreno Valley of Colfax County, although one check block was on

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[1] The use of trade, firm or commercial names in this publication is for information only. No endorsement or approval by the U.S. Department of Agriculture is implied.

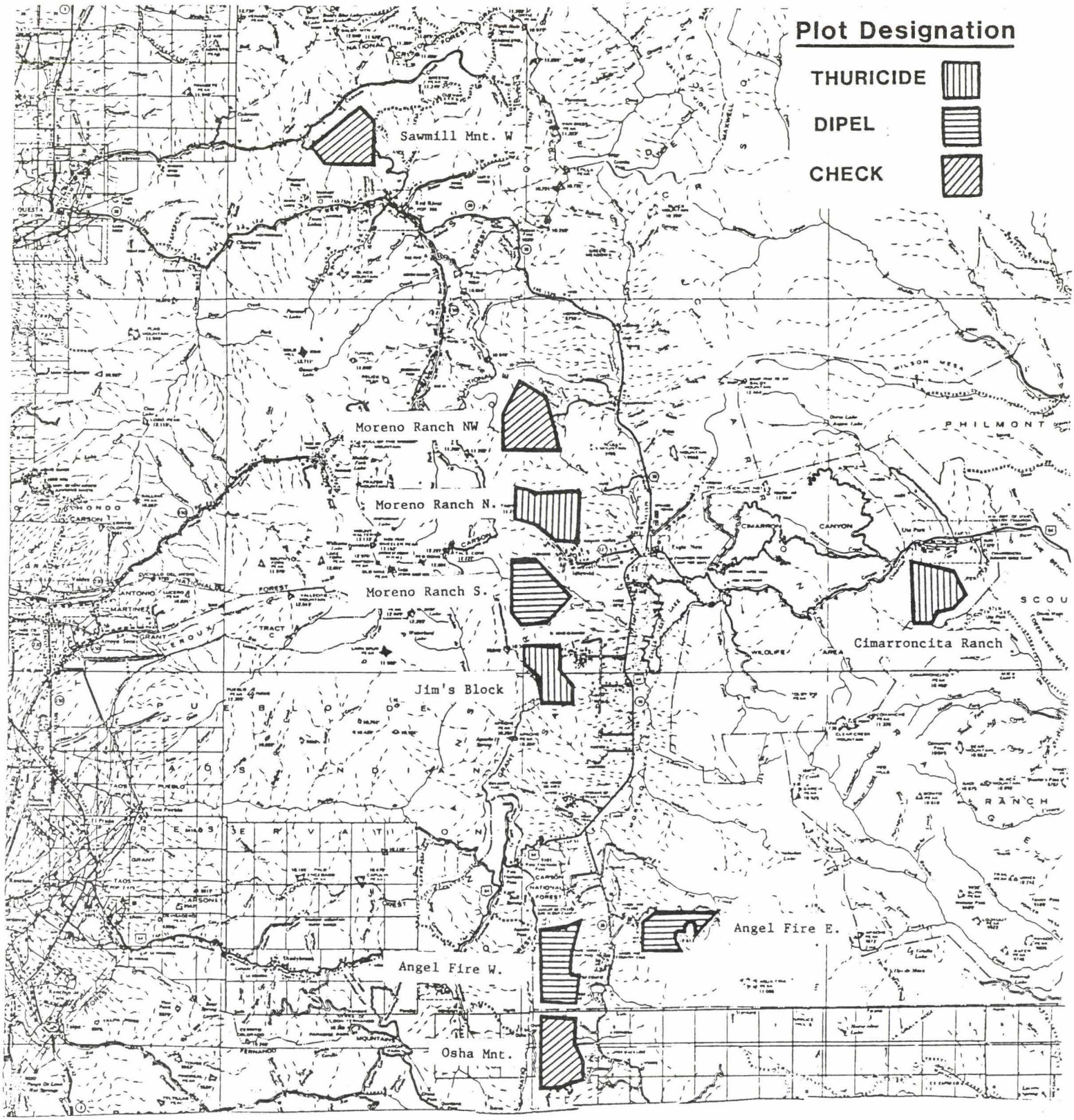

FIGURE 1. Name and location of blocks in the 1981 B.t. Pilot Project.

the Carson National Forest (see map in Figure 1). The topography of of the treated areas consists mostly of mountainous terrain deeply dissected by canyons. Elevations range from 6,000 to 11,000 feet above sea level.

The project area was divided into 9 treatment blocks. Three blocks were treated with Dipel 4L, 3 were treated with Thuricide 16B and 3 served as check blocks. The blocks were selected on the basis of size, age of infestation, western spruce budworm population levels and accessibility. Blocks ranged in size from 1,460 to 2,200 acres. Spray blocks were established in such a way as to eliminate insecticide spray drift between blocks. Where possible, block boundaries followed prominent terrain features or breaks in host type.

The size (acres) and designation of the project blocks are as follows:

Treatment Blocks

Block No.	Block	Acres	Treatment
1	Angel Fire West	1,610	Dipel
2	Angel Fire East	2,152	Dipel
3	Moreno Ranch South	2,213	Dipel
4	Moreno Ranch North	1,885	Thuricide
5	Cimarroncita Ranch	1,514	Thuricide
7	Osha Mountain	1,469	Control
8	Sawmill Mountain West	1,468	Control
9	Moreno Ranch Northwest	1,470	Control
10	Jim's Block	1,905	Thuricide
	Total Acres	15,686	

Figure 1 shows the name and location of each block.

Project Sampling

Four sampling schemes were designed to determine the effect of B.t. applications on spruce budworm larval population densities and host tree defoliation, to determine timing of insecticide application and to quantify insecticide deposition on treated areas. Data was collected for 3 years following the insecticide application, however, not all sampling schemes were conducted during each project year or in each of the project blocks. Table 1 shows the type of sampling conducted for each of the project years.

Within each treatment block, sampling was conducted on tree cluster plots according to the methodology described by Ragenovich (1983). Twenty-five tree cluster plots were established within each block. Clusters were distributed along roads or other accessible areas and were about 1/10 mile apart. One tree was selected at each cluster strictly as a larval development sampling tree. Sample trees were open-grown Douglas-fir, averaging 30 feet in height with full crowns, and were located within a 1-acre area.

Table 1--The different types of sampling conducted during each year of the pilot project to assess the operational value of B.t. for control of western spruce budworm.

	Type of Sampling Scheme	Year Conducted 1981	1982	1983
1.	Insecticide application sampling			
	A. Spray deposition	x		
2.	Pest Population Sampling			
	A. Larval density - pre-spray	x		
	B. Larval density - post-spray	x	x+	
	C. Egg mass density - post-spray	x	x*	x*
3.	Host Tree Sampling			
	A. Damage assessment (Defoliation)	x	x*	x*
4.	Developmental Sampling			
	A. Larval Development	x		
	B. Host tree (Bud) Development	x		

* This type of sampling was not conducted in Block 9 during this year.
+ This type of sampling was not conducted in Blocks 3, 4, 9 and 10 during this year.

Sample plots were used to obtain the following information:

1. Spray deposit assessment to determine whether any insecticide reached that site.

2. Bud and larval samples to determine timing of application.

3. Larval samples to determine effectiveness of the insecticides through pre- and post-spray populations.

4. Estimate foliage protection.

5. Egg mass samples to estimate populations for the following year.

Insecticide Products

Two formulations of Bacillus thuringiensis Berliner were used on the pilot project. The formulations were Dipel 4L[1] and Thuricide 16B.[2] Both products are commercial formulations of the HD-1 strain and contain both the spores and the crystalline endotoxin produced by the bacterium.

The B.t. formulations were applied at a final volume of 1 gallon per acre and a dosage rate of 8 BIU per acre. Tank mixes for the formulations applied were:

1. Thuricide 16B, mixed 1:1 with water and 0.1 percent Rhodamine B extra soluble dye (1 pound per 100 gallons).

2. Dipel 4L, mixed 1:3 parts water and 0.1 percent Rhodamine B extra soluble dye (1 pound per 100 gallons). The formulations were mixed on a per load basis with batch sizes averaging 200 gallons. Two 1/2-pint samples were taken from the formulated tank mixtures for bioassy to determine potency.

Applications

All operations for insecticide applications were conducted from the Angel Fire Airport. Spray blocks were treated when 50 percent of the budworm larvae were in the fourth instar and when there was sufficient foliage exposed for target.

Two fixed-wing aircraft were used to make the insecticide applications. One aircraft was a Turbo Air Tractor 302 with a 385 gallon spray tank capacity and a rated power of 600 horsepower. During the spray operations, it carried between 200 and 270 gallons of formulated material. The second aircraft was an Air Tractor with a radial engine. This aircraft was also rated at 600 horsepower but was only used for applications at lower elevations because of its non-turbo characteristics.

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[1] Abbott Laboratories
[2] Sandoz Corporation

The aircraft spray systems consisted of 31-32 nozzles (Fulljet 1/8 GGA 8W) and were operated at 40 psi. The insecticide applications were conducted at an aircraft speed of 150 miles per hour with an insecticide release height of 50 feet above the forest canopy and an effective spray swath of 150 feet.

Aircraft were calibrated for 1 gallon per acre, and insecticide atomization was determined by the D-Max method (Dumbauld and Rafferty 1977). The average VMD obtained for Thuricide 16B and Dipel 4L was 221U and 239U, respectively.

Meteorology--During the operation, area forecasts were provided each day by the National Oceanic and Atmospheric Administration Office in Albuquerque, New Mexico.

Prior to, and at 30-minute intervals during treatment, surface observations of temperature, relative humidity, cloud cover, wind speed, and wind direction were taken at the airport. In addition, at 15-minute intervals, temperature, wind speed, direction, and relative humidity were measured from a position within the treatment block.

Spraying was terminated when any of the following conditions exsisted: When wind speed, as measured in the treatment block, exceeded 6 miles per hour; when ambient temperature exceeded 70 degree F; or when thermal lifting of the insecticide spray was noted by the aerial observer. Appendix A shows the dry temperature and relative humidity for each spray date.

RESULTS AND DISCUSSION

I. SPRAY DEPOSITION

Spray deposit data collected during the insecticide applications show that there is less variability in each of the parameters use to characterize spray deposition and coverage for Dipel 4L (Table 2). This indicates that the Dipel 4L applications resulted in more consistent insecticide coverage between blocks inspite of the greater volume of water in the insecticide mixture. For example, the volume median diameters (VMD) for the Dipel 4L blocks were 242u, 231u and 243u compared to 219u, 174u and 271u for the Thuricide blocks. The number median diameters (NMD) also indicate the same consistency of application for Dipel blocks. The NMD's for the treatment blocks were 45u, 42u, 42u for Dipel, and 69u, 100u, 79u for Thuricide.

Differences in evaporation rates between the two formulations could have affected the amount of insecticide deposited in each block due to varing weather conditions during application. Certainly, a large evaporation rate for the Thuricide mixture could explain the variability observed. Dennison and Wedding (1984) determined the evaporation rate of droplets of various pesticide mixtures containing water and oil. In controlled tests with temperature and humidity conditions similar to those occurring during spray operations (RH=30-60%, Temp. -2 to 20 C), these authors reported that a 100u droplet of Thuricide 16B (diluted 1:1 with water) lost 41% of its mass over a time period of 4-9 seconds. Although larger droplets took a

Table 2--Spray deposit data for Dipel 4L and Thuricide 16B on the B.t. pilot project, 1981.

	Dipel 4L			Thuricide 16B		
Blocks	1	2	3	4	5	10
Volume median diameter[1]	242	231	243	219	174	271
Volume mean diameter[2]	253	248	260	263	210	299
Number median diameter[3]	45	42	42	69	100	79
Number mean diameter[4]	75	62	73	84	105	95
Drops/cm^2	3	7	4	17	6	7
Gallons/acre[5]	.03	.04	.05	.16	.08	.11

[1]Volume median diameter (VMD)--The drop diameter at which 50% of the volume is in drops larger and 50% of the volume is mass in drops smaller than the VMD.

[2]Volume mean diameter--The diameter associated with that drop, not necessarily in the population, for which the average drop volume is found.

[3]Number median diameter (NMD)--The drop diameter which divides the total drop populations in half, with half the drops larger and half smaller than the NMD.

[4]Number mean diameter--Average diameter of the drop population, independent of volume.

[5]Gallons per acre--Amount recovered on Kromekote cards. Application rate for Thuricide and Dipel was 1 gallon per acre.

longer period of time to evaporate the same percentage of mass loss, all droplets loss maximum mass (60%) before descending 300 feet.

Droplet density for all treated blocks was below (3-17 drops 1 cm^2) the amount normally needed for acceptable results. From operational experience (Morris 1980) it has been observed that acceptable insect control is achieved when insecticide droplet density on Kromekote cards is greater than 21 drops/cm^2. Although Kromekote cards are not a precise indicator of insecticide deposition on foliage, they are a reliable tool for monitoring spray coverage during field operations (Dumbauld and Rafferty 1977).

II. PEST POPULATION DENSITY

Larval Densities

A. Pretreatment Densities--Larval population densities determined from samples taken prior to B.t. application ranged from 20.0 to 33.4 larvae per 100 buds. These population densities are considered to be outbreak levels normally causing heavy tree defoliation but the population levels are within the range for which B.t. use is recommended (Morris 1980). Larval densities occurring before and after insecticide treatment are summarized for each of the project blocks in Table 3. No significant difference in larval populations was found between blocks prior to insecticide application.

B. Post Treatment--In samples taken at different time intervals (7, 14 and 21 days) after treatment during 1981 (Table 3), significant differences in larval densities were found between the latter two sample periods. At 14 days after treatment, there was a significant difference in larval densities between Thuricide and Dipel and between Thuricide and the check. At 21 days after treatment, significant differences occurred between the two insecticide formulations and the check. At the $--\alpha \leq .05$ level, there was no significant difference between the Dipel and Thuricide treatments, however, at the $--\alpha \leq .10$, there is a significant difference between the two treatments.

Differences in larval densities also occurred within treatments through time. It appears that the effect of Thuricide on budworm populations occurs about 7 days earlier than the effect of Dipel. Figure 2 graphically illustrates the changes which occurred in average numbers of larvae per 100 buds from prespray through 21 day postspray for each treatment.

Unadjusted larval mortality in the 21 day samples ranged from 54.5 percent for Check Block 8 to 93.7 percent for Thuricide Block 5. When natural mortality was taken into account, the percent mortality attributed to the effect of B.t. applications was not as high as expected for effective control. Percent adjusted mortality was lower in the Dipel blocks (x=49.6%) than in the Thuricide blocks (x=70.3%). Even though the percent kill was not high, the actual effectiveness of the B.t. applications is reflected by the residual budworm population. Larval populations in 1981 were reduced to the effective control threshold of 5 larvae per 100 buds (Telfer 1982).

In 1982, larval data were again collected in the project area by an associated study. These data was used to determine the effect of B.t.

Table 3--Larvae per 100 buds before and after treatment using 2 formulations of B.t. in pilot project in New Mexico, 1981

Larval Densities per 100 Buds

Block	Prespray	7-day Postspray	14-day Postspray	21-day Postspray	% Unadjusted Mortality	% Adjusted Mortality[1]
1	25.2	12.6	9.2	5.6	77.8	44.4
2	24.7	10.7	8.7	5.4	78.1	45.4
3	33.4	21.0	8.8	5.5	83.5	59.0
4	29.8	20.3	5.7	4.0	86.6	66.2
5	23.7	10.7	2.6	1.5	93.7	84.3
10	23.3	13.2	5.7	3.7	84.1	60.4
7	32.1	25.7	19.5	13.6	57.6	
8	20.0	11.8	11.7	9.1	54.5	
9	30.4	25.4	12.5	10.0	67.1	

[1]Adjusted by Abbott's formula.

$$1 - \frac{\text{Post-treatment}}{\text{Pre-treatment}} \times \frac{\text{Pre-check}}{\text{Post-Check}} \times 100$$

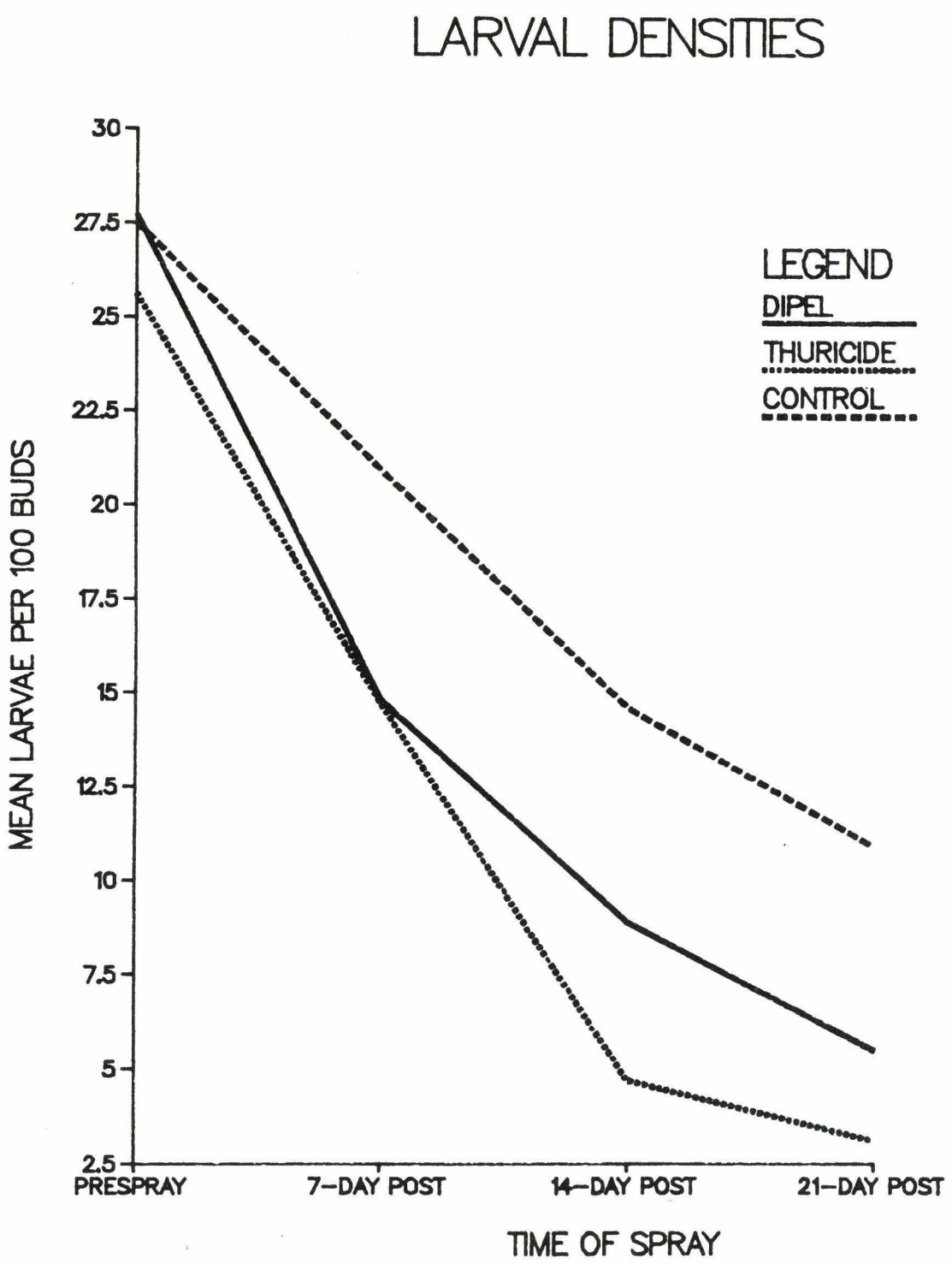


Figure 2. Mean number of larvae per treatment in branch samples taken at different time intervals in the 1981 Pilot Project.

Table 4--Prespray and postspray larval densities (number of larvae per 100 buds) used to evaluate efficacy of B.t. applications.

		21-day Postspray	
Block	1981 Prespray[1]	1981	1982
1	25.2	5.6	5.2
2	24.7	5.6	7.3
3	33.4	5.5	--
4	29.8	4.0	--
5.	23.7	1.5	1.3
10	23.3	3.7	--
7	32.1	13.6	17.7
8	20.0	9.1	16.0
9	30.4	10.0	

[1]Larval data were collected in 1981 prespray and 1982 at approximately the same time during larval development.

on budworm populations one year after application. Due to a suppression project conducted on adjacent private land by the state of New Mexico, larval samples were available for only five of the nine blocks in the project (Table 4). The sampled blocks were: 1 (Dipel), 2 (Dipel), 5 (Thuricide), 7 (Check), and 8 (Check).

Using the available 1982 larval data for these five blocks, Ragenovich (1983) reported a significant difference in larval densities between the B.t. treated blocks and the check blocks. The reported significance resulted in spite of an F-value based on only one replication (block) for Thuricide and two replications for Dipel and the Check. In assessing the significance of these results, one must consider the statistical weight of data collected from only one replication. In addition, it must be pointed out that block 5 (Thuricide) was located (Figure 1) in an isolated area which may have had a different rate of adult migration than the Dipel blocks particularly since the latter were adjacent to untreated areas. Nevertheless, when prespray larval populations were compared to postspray larval populations occurring one year after treatment significantly lower larval densities were found on the B.t. blocks. The difference in larval densities between the treatment and check blocks can be attributed to a population reduction caused by the biological insecticide.

Egg Mass Densities

Changes in egg mass density by treatment block are given in Table 5 and are graphically illustrated in Figure 3. During each of the project years, egg mass densities were lowest in the Thuricide blocks. In contrast, egg mass densities increased each year in both the Dipel and the Check blocks.

No statistical difference in egg mass densities was found in 1981 and 1983 between the treated and untreated blocks inspite of the large differences in larval densities. These results are somewhat confusing since the reduction in larval populations resulting from B.t. applications in 1981 were expected to be followed by a significant difference in egg mass densities between treated and untreated blocks. The lack of significance, in part, may have been due to a large sample variance. It may also have been due to migration of egg laying moths from surrounding infestations.

For 1982, differences in density were found between the two B.t. formulations and between Thuricide and the Check. A significant difference in egg mass density was again found between Thuricide and Dipel in 1983.

Table 6 contains the results of Student t tests using block means to determine treatment effects on egg mass density for all three years. In the Thuricide blocks, egg mass densities were significantly lower (≤ 0.10) in 1981 than they were in 1983. The same difference was found between Thuricide in 1981 and the Dipel blocks in 1983. During the latter year, Dipel treated areas had significantly higher egg mass populations than the Thuricide treated blocks for the same year.

As expected, egg mass densities were highly variable during each of the years of the project. Statistical analysis of the egg mass data

Table 5--Egg mass densities (average number of egg masses per m^2 foliage) for each project block by sample year.*

Block Number/Treatment	Sample Year 1981	1982	1983
Dipel			
1	21.6	17.3	43.5
2	6.6	11.1	36.3
3	1.9	4.6	39.7
Thuricide			
4	1.3	1.3	7.7
5	0.7	0.9	9.4
10	3.3	3.2	6.9
Control			
7	4.3	17.2	23.1
8	15.5	22.1	32.1
9	4.4	--	--

*First two years data from Ragenovich, 1983.

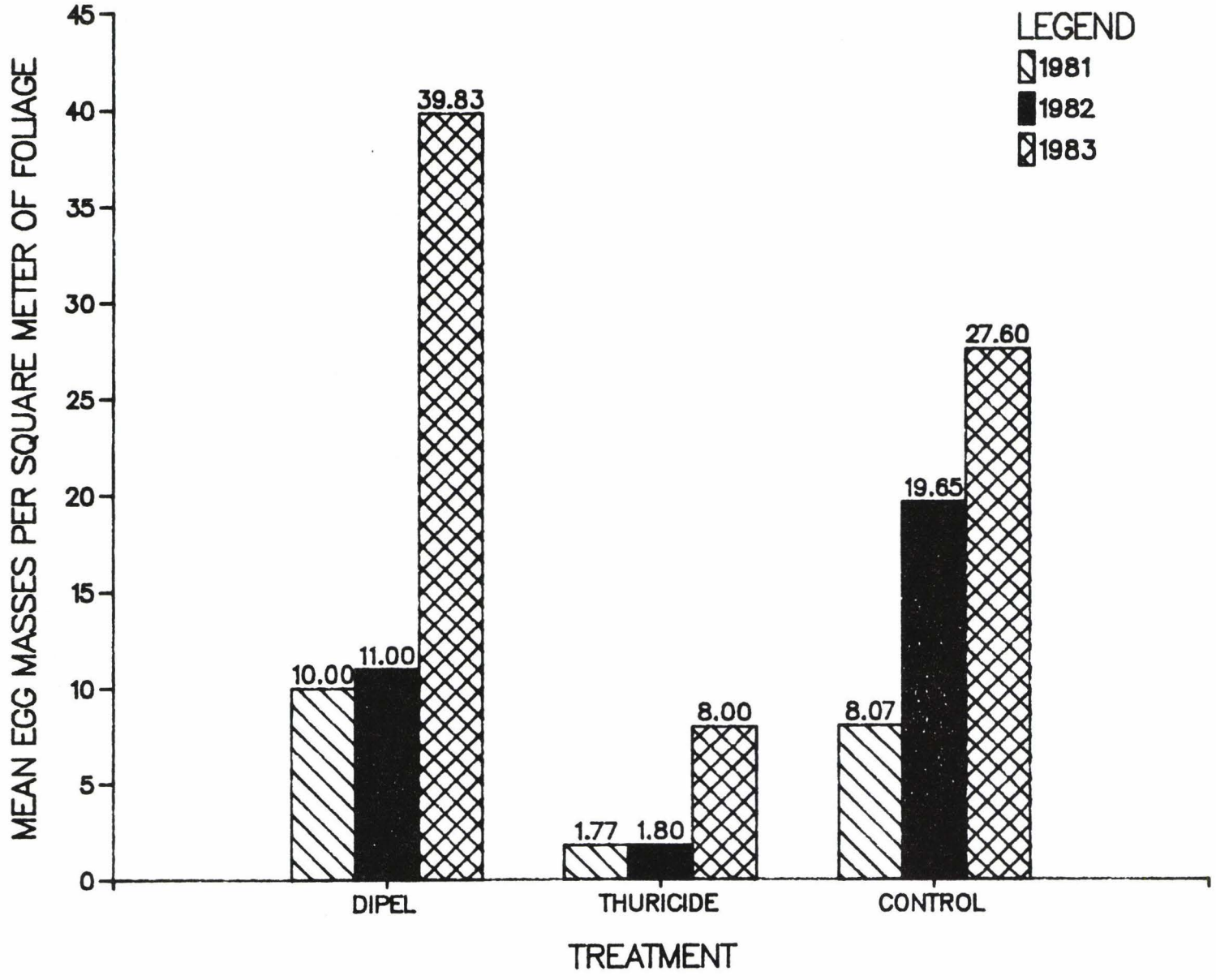


Figure 3. Mean number of new egg masses in each treatment for sample years 1981-1983.

Table 6--Results of Student-t test using block means to determine treatment effect on egg density by year.

Year	Treatment	Treatment Mean ($\#EM/M^2$)	Std. Dev.	Sample Size
1981	Thuricide	1.77 a*	1.36	3
	Dipel	10.03 ab	10.29	3
	Check	8.07 abc	6.44	3
1982	Thuricide	1.80 abcd	1.23	3
	Dipel	11.00 abcde	6.35	3
	Check	19.65 b ef	3.47	2
1983	Thuricide	8.00 bc efg	1.28	3
	Dipel	39.83 h	3.60	3
	Check	27.60 a d fgh	6.36	2

* Treatments having the same letter are not significantly different from each other at the 10% level of probability.

were conducted using both sample point mean density and treatment block mean density. From these analyses, it was learned that egg mass densities varied greatly from block to block and year to year irregardless of data manipulation. Even within blocks, a large variation in densities occurred between sample points for any given year.

This suggests that egg mass densities were not a strong indicator of larval population changes. At low larval density, egg mass sampling may have missed the presence of budworm at a point when the budworm was present. At high larval density, the migration of the budworm may have evened out the egg mass densities in the samples. For this reason, egg mass densities should not be the only factor used in evaluating the success of B.t. applications.

III. FOLIAGE PROTECTION

The amount of tree defoliation occurring during 1981-1983 for each of the project blocks is presented in Table 7 and is illustrated in Figure 4.

When the percent defoliation occurring during the year of treatment (1981) was analyzed, no significant difference was found between the treated and the untreated blocks, indicating that B.t. applications did not provide significant foliage protection in the year of treatment.

A partial explanation for these results may be provided by the larval population data. Although the amount of mortality caused by the insecticidal applications was low (44.4 - 84.3% adjusted) (see Table 3), the residual population densities at 21 day postspray are at or below the effective control threshold (5 larvae per 100 buds) for foliage protection (Telfer 1982). This threshold level is not achieved until 14 days after application for the Thuricide formulation and 21 days for the Dipel formulation. What the data suggests are that the toxic action of both B.t. formulations is not rapid enough to prevent damage by the target population during the year of treatment.

Another explanation for the observed results in the insecticide applications may be understood when one considers the feeding behavior of the insect. Budworm larvae feed exclusively on succulent current year growth. Budworm damage (defoliation) is the result of larval feeding on the growing buds. Developing and fully flushed buds constitute a small percent of the total foliage on a tree and therefore contain a small amount of the insecticide deposited. To ingest a lethal dose of B.t. the larvae must consume a large amount of foliage over a considerable period of time. Consumption of the amount of treated foliage needed to produce toxic effects by B.t. results in extensive tree damage.

Percent defoliation in 1982 decreased from the level occurring the previous year; however, the decrease in defoliation was significantly lower only in the treated blocks (Table 8). Furthermore, a significantly lower amount of defoliation occurred in the Thuricide blocks as compared to the Dipel blocks. The reduction in foliage damage occurring in the treated blocks was was believed to be due to lower residual larval populations (see Table 4) in 1982.

Table 7--Amount of tree defoliation (percent) occurring for each year after application of Bacillus thuringiensis to control the spruce budworm. New Mexico, 1981.

	Defoliation Rating (%) Year		
Treatment/Block No.	1981	1982	1983
Dipel			
1	75.0	15.5	47.2
2	78.1	20.0	29.5
3	89.1	13.0	5.0
Thuricide			
4	96.1	5.6	1.2
5	76.5	3.2	3.1
10	64.9	8.0	2.1
Check			
7	87.5	51.2	34.4
8	74.0	81.6	63.0
9	97.3	--	--

*Data for 1981 and 1982 from Ragenovich, 1983.

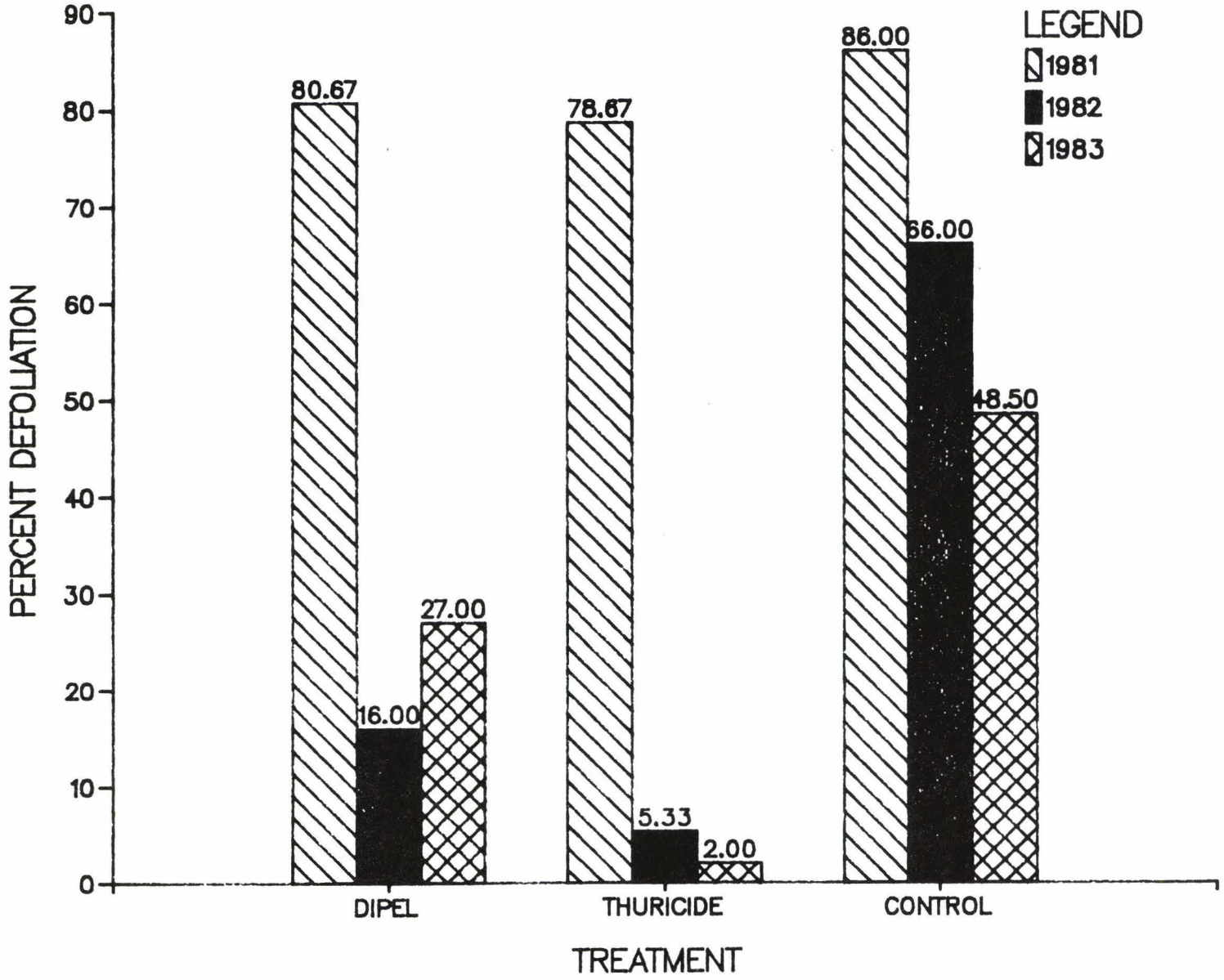


Figure 4. Changes in mean defoliation occurring during 1981-1983 for each treatment in the 1981 Pilot Project.

Table 8--Results of Student-t test using block means to determine treatment effect on the percent of defoliation by year.

Year	Treatment	Treatment Mean (% Defoliation)	Std. Dev.	Sample Size
1981	Thuricide	79.17 a*	15.77	3
	Dipel	80.73 ab	7.41	3
	Check	86.27 abc	11.70	3
1982	Thuricide	5.60 d	2.40	3
	Dipel	16.17 e	3.55	3
	Check	66.40 abcdef	21.50	2
1983	Thuricide	2.13 d fg	0.95	3
	Dipel	27.23 defgh	21.19	3
	Check	48.70 abcdefgh	20.22	2

*Treatments followed by the same letter are not significantly different from each other at the 10% level of probability.

Defoliation for 1983 remained low in the Thuricide treated blocks. In the Dipel blocks, it increased significantly over the previous year but remained the same in the Check blocks. Since no determination of larval populations was conducted for this year, it is assumed that these differences occurred because of increasing populations which can be predicted from the egg mass densities occurring in 1982.

CONCLUSIONS

In the 1983 progress report, Ragenovich made several conclusions and recommendations which were based on the 1981-82 data. After consideration of all the data available, the following conclusions are made:

1. Applications of Bacillus thuringiensis are effective in maintaining budworm larval populations at a low level for two consecutive years. A comment should be made concerning this conclusion. The second year data which was used to support the conclusion of second year population reduction is based on larval densities in samples taken from only one Thuricide replication, a fact which weakens the reliability of the data.

2. No significant reductions in population levels were found in samples taken 7 days posttreatment; therefore, this sample period could be eliminated from the evaluation sampling scheme. Since treatment effect showed up earlier (at the 14-day sample) for Thuricide than for Dipel timeing of the sampling may depend on the formulation.

3. No operational problems with mixing or loading of either insecticide product were encountered. However, evaporation of the diluted formulation indicates that application parameters are very important and can affect the insecticide coverage and deposition. By applying these products undiluted (Neet) more consistent application between blocks may be achieved.

4. No significant reductions in defoliation were found during the year of treatment; therefore, no foliage protection was achieved the first year after application of B.t. The amount of defoliation occurring in treated areas does appear to be lower in the second and third year after treatment.

5. Statiscally, treatment and block variation increased with time making the detection of treatment differences impossible. This could be an indication that treatment effects over a period of three years are masked by other factors that treatment benefits cannot be evaluated unless the areas are very similar and located directly adjacent to each other.

REFERENCES

Dumbauld, R.K. and J.E. Rafferty. 1977. Field manual for characterizing spray from small aircraft. USDA Forest Service, Missoula, MT, Report TR-76-113-02. 68 p.

Dennison, R.S. and J.B. Wedding. 1984. Determination of evaporation rates of pesticide droplets. USDA Forest Service, Missoula, MT, Report 8434-2801. 175 p.

Ragenovich, I.R. 1983. Pilot project to evaluate the operational use of Bacillus thuringiensis against the western spruce budworm in northern New Mexico, 1981-82. USDA Forest Service, Report R-3 84-1.

Morris, O.N. 1980. Report on the 1980 cooperative Bacillus thuringiensis (B.t.) spray trials. Rep. FPM-X-48. Sault Ste. Marie, ON: Canadian Forestry Service, 75 pp.

Telfer, W.G. and J.P. Linnane. 1984. Western spruce budworm suppression project, 1983. USDA Forest Service, Albuquerque, NM, Report 84-14. 17 p.

Bennett, D.D. and J.P. Linnane. 1985. Western spruce budworm suppression project, 1984. USDA Forest Service, Albuquerque, NM, Report 85-11. 42 p.

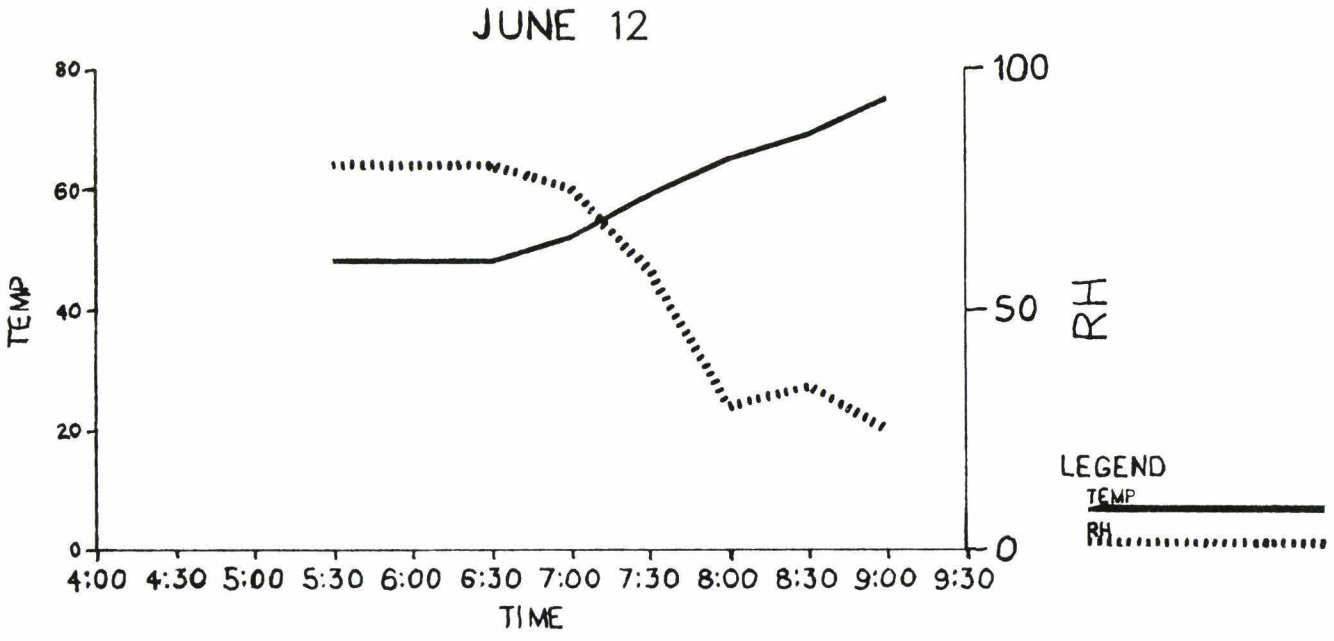
Rogers, T.J., J.M. Chavez, and J.P. Linnane. 1985. Western spruce budworm suppression project using Bacillus thuringiensis Berliner, 1984. USDA Forest Service, Albuquerque, NM, Report 85-6. 15 p.

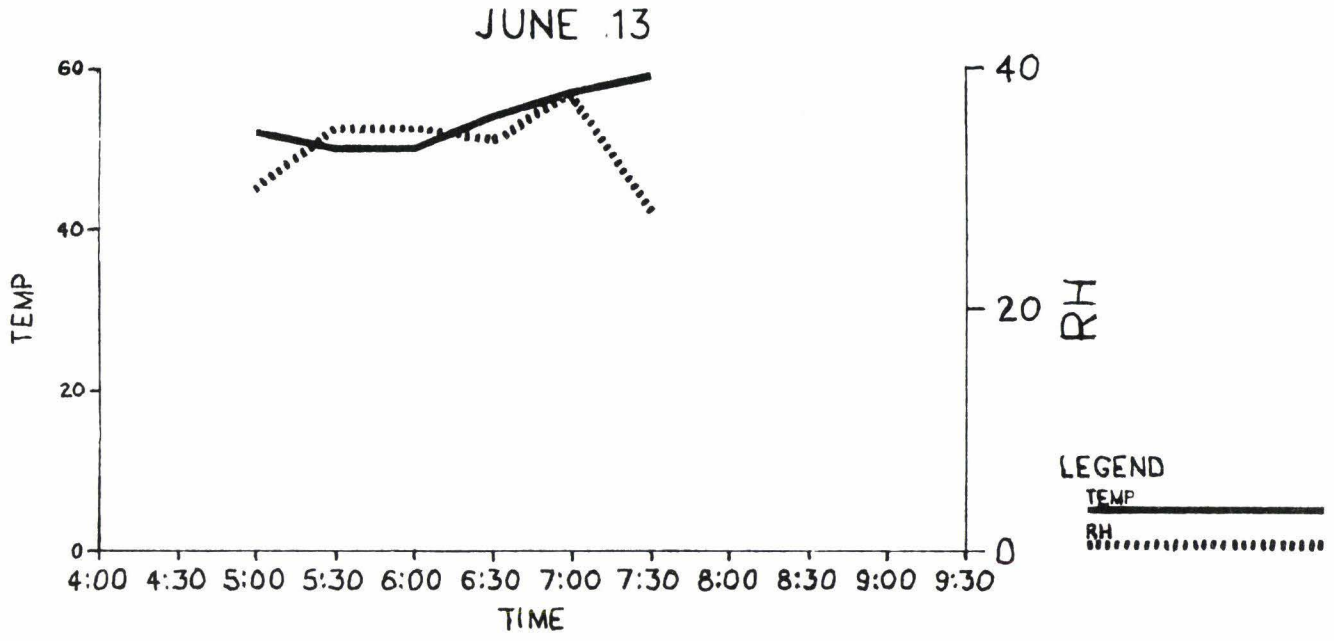
Rogers, T.J. 1986. Suppression of western spruce budworm infestations in high-use recreational campgrounds with Bacillus thuringiensis and Acecap 97 systemic tree implants. USDA Forest Service, Albuquerque, NM, Report 87-1. 12 p.

Morris, O.N. 1980. Report on the 1980 cooperative Bacillus thuringiensis (B.t.) spray trials. Rep. FPM-X-48. Sault Ste. Marie, ON: Canadian Forestry Service, 75 pp.

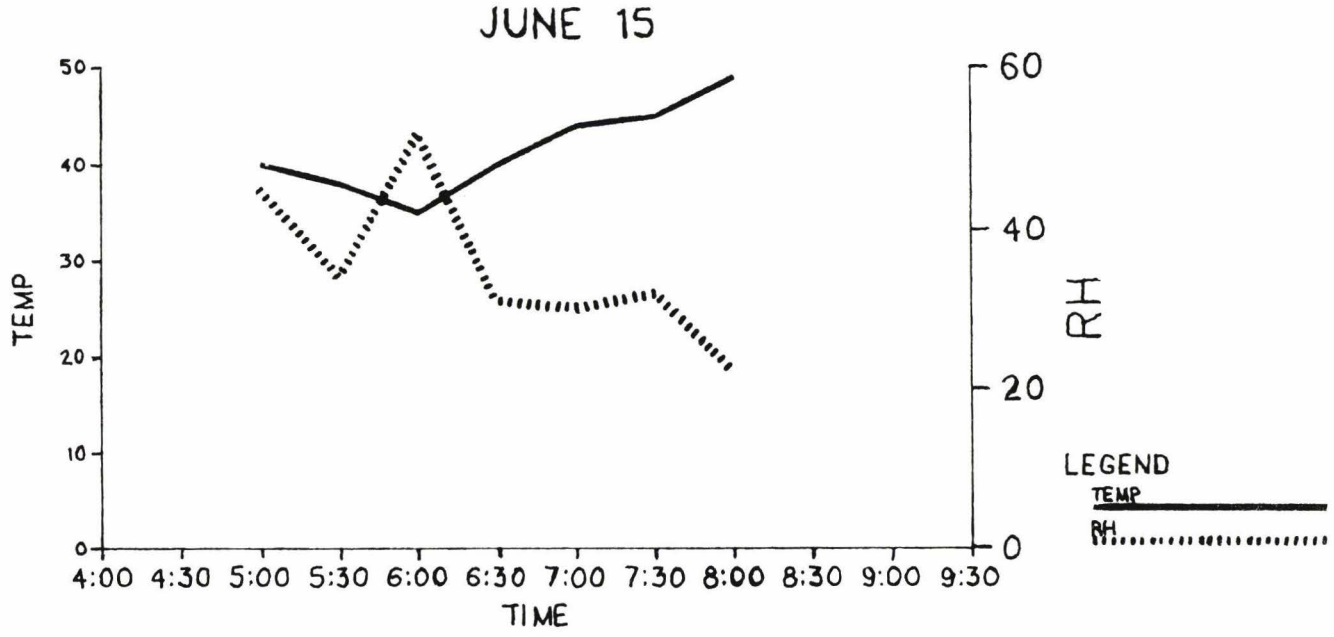
APPENDIX A

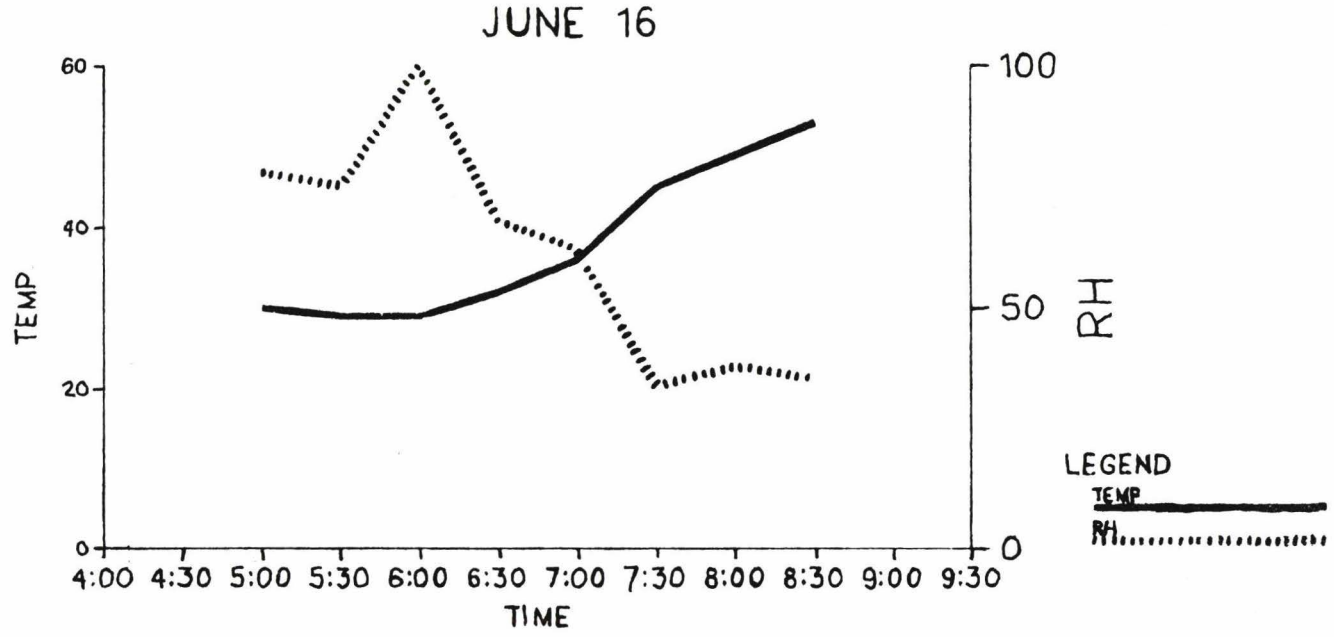
METEOROLOGICAL CONDITIONS DURING SPRAY OPERATIONS



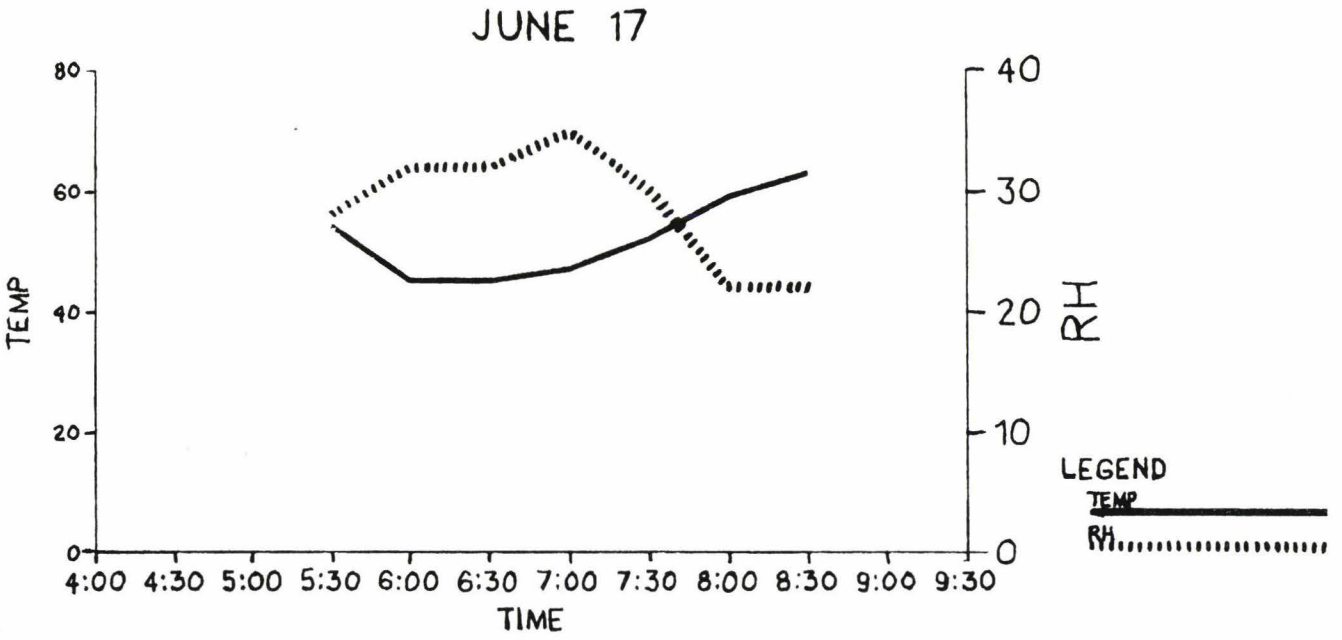


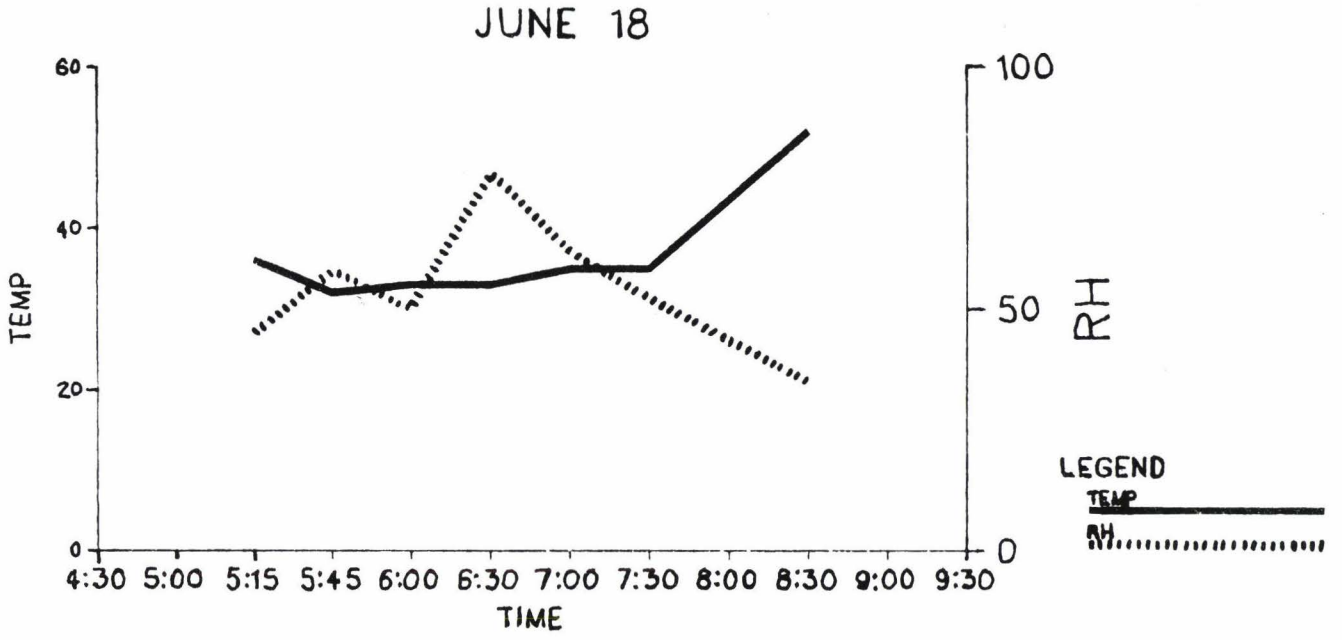
APPENDIX A.--Relative humidity and temperature charts for days of spray application





APPENDIX A.--Relative humidity and temperature charts for days of spray application--continued





APPENDIX A.--Relative humidity and temperature charts for days of spray application--continued